



# CYGNSS: Lessons We are Learning from a Class D Mission

**Jessica Tumlinson**

Lead EEE Parts Engineer

Southwest Research Institute      San Antonio, TX  
[jtumlinson@swri.org](mailto:jtumlinson@swri.org)      210.522.6222



# Agenda

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- Who is SwRI?
- What is CYGNSS?
- How CYGNSS compares
- Factors in defining CYGNSS parts program
- CYGNSS Parts Control Board
- Parts selection for CYGNSS
  - The details aren't as important as the how and why
- Additional challenges experienced
- Tips for success
- Conclusions



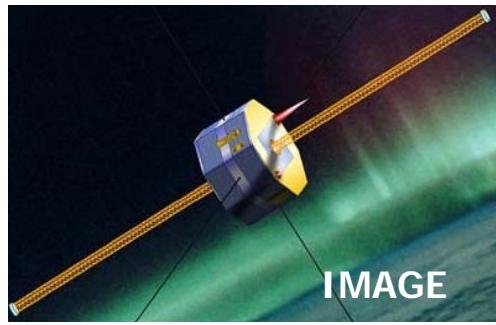
# Who is Southwest Research Institute (SwRI)?

- Independent, nonprofit applied research and development organization
- Space Science and Engineering Division one of 10 technical divisions with a dedicated focus in the physical sciences
- World Class Space Science Research, Space Avionics, and Instrument Development
- Mission level expertise includes large and small Mission Project Management and/or Mission Systems Engineering
- Stand alone services include project management, systems engineering, manufacturing, parts engineering, and earned value management (EVM)
- Extensive experience and expertise in the design and build of spacecraft electronics, instrument electronics and instruments for NASA, non-NASA US Government, international, and Commercial customers
  - Parts requirements run the gamut from Class B (Level 1 parts, DX rated) projects to Class D
    - Historically, EEE-INST-002 Level 2 is most common parts program

# Sample of Missions SwRI has Supported



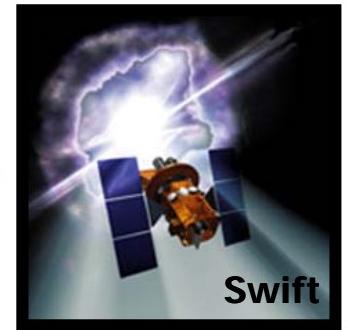
Cassini



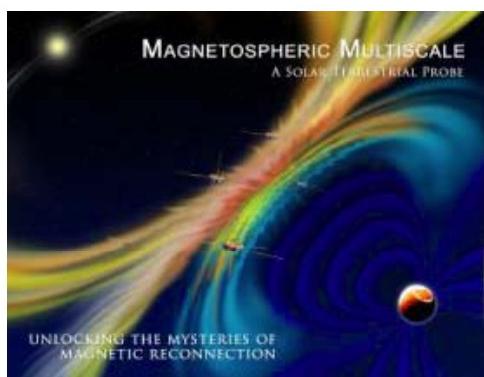
IMAGE



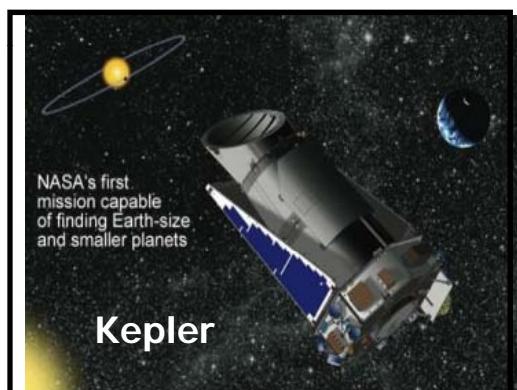
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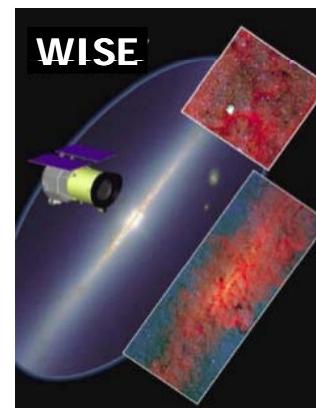
Swift



UNLOCKING THE MYSTERIES OF MAGNETIC RECONNECTION



Kepler



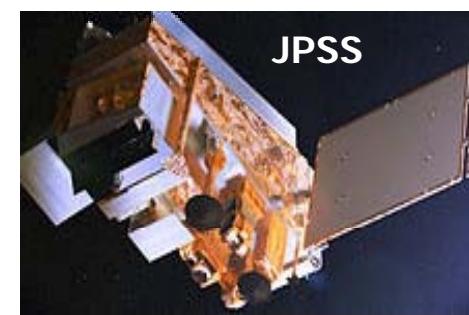
WISE



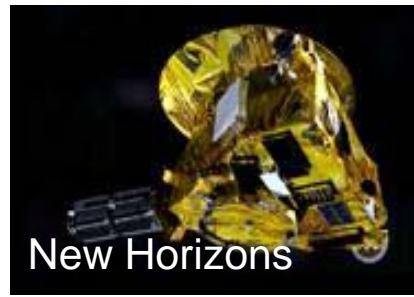
WorldView 1 & 2



Deep Impact



JPSS



New Horizons



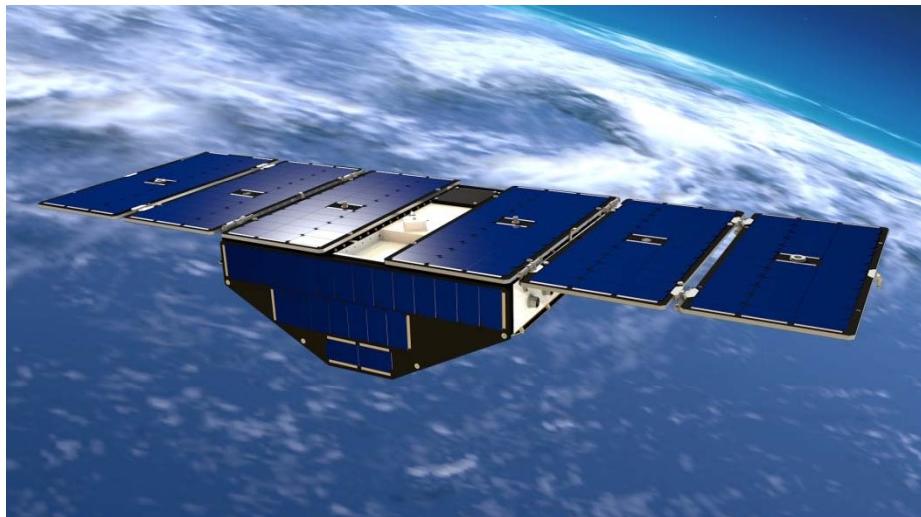
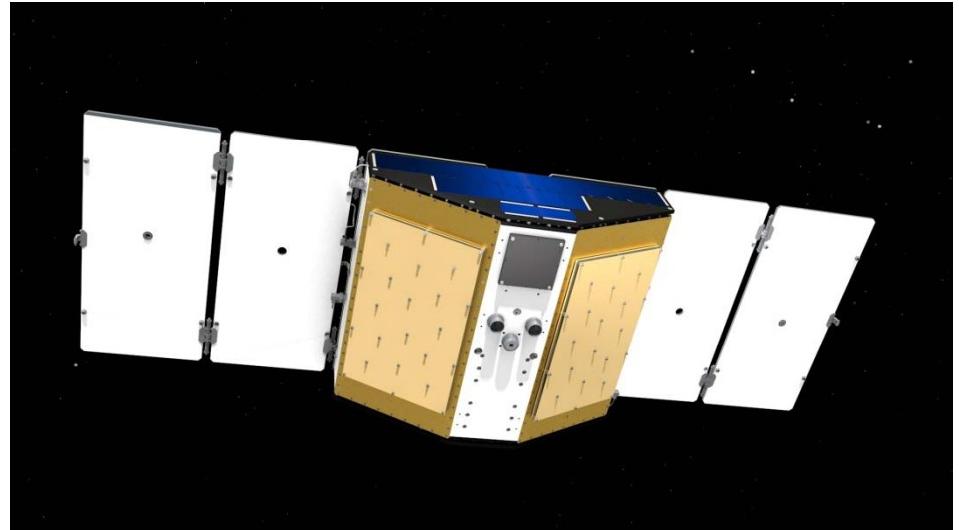
IBEX

65+ missions with 100% mission success



- Cyclone Global Navigation Satellite System
- CYGNSS consists of 8 Global Positioning System (GPS) bi-static Global Navigation Satellite System Reflectometry (GNSS-R) receivers deployed on separate micro-satellites

## What is CYGNSS?



## CYGNSS Science Goal

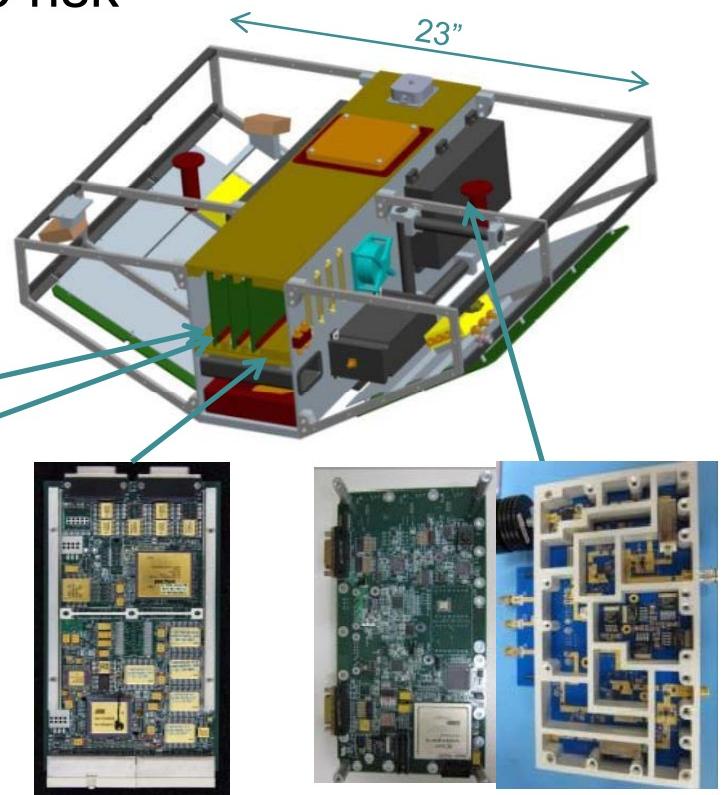
Understand the coupling between ocean surface properties, moist atmospheric thermodynamics, radiation, and convective dynamics in the inner core of a tropical cyclone



# What is CYGNSS?



- The CYGNSS mission is the NASA Earth Venture 2 Mission selected in June 2012
- PI-led mission
- CYGNSS is classified as Category 3 Class D
  - Low cost, highest level of acceptable risk
- Cost and schedule capped
- Project currently FM fabrication
  - CDR completed January 2015
  - Launch scheduled for October 2016





# Comparison of CYGNSS to other kinds of Projects

	SwRI Designed CubeSat	CYGNSS	MMS
Mission Category	CubeSat	Class D	Class B
# of S/C	1 CubeSat	8 MicroSats	4 satellites
Mission Profile	<1 year LEO Orbit	2 years LEO Orbit	2 years Elliptical Earth Orbit
Size	4-16 kg	28.9 kg/ satellite	1326 kg/ satellite
Customer	Variety	PI	NASA GSFC
NASA Center	Varies, none in some cases	LaRC	GSFC
Payload	N/A	1	25 instruments
Mission Success	3 months science data	6 months of data with 4 uSats	As defined by NASA MMS Level 1 requirements; some instruments can be lost, case by case basis



# Comparison of CYGNSS to other kinds of Projects

	SwRI Designed CubeSat	CYGNSS	MMS
Mission Budget	\$2-5M	\$100M	\$1B
Cost per satellite	\$2-5M	\$4.9M, not including payload	\$165M
Parts Cost	\$25-100K; 20% of total cost	\$281K not including payload; 6% of total cost	\$50M/ satellite; 30% of total cost
Mission Assurance Approach	Best practices and design reviews; no formal QA	SMA delegated to PI; NASA is reviewer; Significant negotiation during Phase A for requirements with NASA	Customer provided MAR; limited flexibility during negotiations
Contractual EEE Parts Requirements	None	None	EEE-INST-002 Level 2
Customer provided Parts Control Plan?	No	No	Yes



# How did CYGNSS select a Parts Program?

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- Careful balance between cost constraints and mission risk profile
- CYGNSS needed more reliability and radiation tolerance than traditional CubeSat parts programs
- The CYGNSS mission achieves reliability through mission and system level factors rather than through simple piece part reliability such as the traditional Level 2 or Level 3 parts program
- Approach similar to LADEE, System F6, various commercial S/C programs
- Aims to find the balance between
  - Cost
  - Risk
  - Schedule (short development cycle)
  - Technology available
    - We could not meet the technical requirements imposed using currently available space qualified components
- Team chose to be aggressive given Class D mission and functional redundancy



# CYGNSS Parts Control Board

- **There is still a mission level Parts Control Board**
  - Consists of Mission Parts Engineer, Mission Radiation Engineer, Mission QA and Hardware Developer Parts Representative
  - NASA LaRC is not a voting member
- **There is still a mission level Parts Control Plan**
  - Generated by SwRI
  - Includes requirements for
    - Comprehensive GIDEP searches of all flight parts
    - Procurement from OEMs or authorized distributors to mitigate the risk of counterfeit parts
- **Approval broken into two categories**
  - Parts Quality
    - Approach based primarily on part reliability rather than traditional screening
  - Radiation
    - ICs and transistors only for this environment
  - A part cannot be fully approved until both categories have been satisfied
- **PIL, PAPL, ADPLs and ABPLs still required**
  - Formats less prescribed, vendor format acceptable for many
- **Additional approaches at higher levels of assembly to assure necessary reliability**
  - Avionics required to undergo burn-in for infant mortality screening
    - Project expects to see more part failures during initial board level testing
  - System redundancy at microsat level is key



# Parts Selection for CYGNSS

- **Determination of what is appropriate occurs on a part by part basis and considers:**
  - Existing radiation data (Radiation Approval)
  - Existing reliability data (Parts Quality Approval)
  - Part Application and Criticality (Both)
- **For active devices, radiation evaluation is paramount**
  - If data is not available, project must decide between changing parts and testing the part (or assembly)
  - Only after that has been determined, can parts quality be reviewed
- **Heritage can factor largely into parts selection**
  - Does not automatically guarantee approval, but does carry weight especially for similar mission durations and orbits



## Additional Challenges

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- **We've encountered additional challenges brought on by extensive use of commercial parts**
  - Pure tin finish is the rule, rather than exception
    - Mitigation approach must be determined and accepted
  - PEDs (plastic encapsulated devices) are the rule, rather than exception
    - Outgassing may be an issue for particular missions
  - Complications to thermal design and analysis at the circuit board level
  - Definition and implementation of derating requirements must be carefully considered
  - Introduces unique manufacturing considerations at the circuit board level
    - Component packages often different from traditional space parts
    - Introduction of plastic packages to a manufacturing process designed for ceramic packages



## Tips for Success

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- **Negotiate parts program early on and ensure customer buy in**
  - Ideally during proposal phase
- **Be sure requirements are captured in the appropriate document**
  - Ex: The Parts Control Plan isn't necessarily the best place for handling and storage requirements for PEDs
    - Those responsible for implementing these requirements not likely to read PCP
- **Supplier engagement can have significant benefits**
  - Reach back into the manufacturing processes utilized by suppliers for process, test, reliability, etc
- **Ensure design engineers understand the kinds of parts available for use and the limitations**
  - Not all commercial parts are acceptable
- **Get creative with parts selection**
- **Part obsolescence may need to be more carefully managed**
- **Don't discount lead times, they may still be an issue relatively**



## Conclusions

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- The CYGNSS team is still learning how to operate in this Class D world
- This approach isn't appropriate for all missions, even all Class D missions
- Class D missions have to find the balance between cost constraints and risk profile
- Still have to apply lessons learned from projects with a more traditional parts program, where reasonable
- Have to be willing to accept more risk than we have been trained to accept
  - Risk still has to be quantified



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